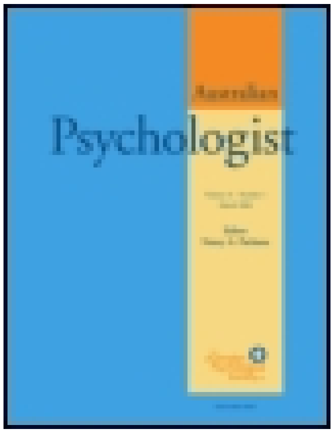

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Effects of cultural background on WAIS-III and WMS-III performances after moderate–severe traumatic brain injury

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Abstract

The assessment of cognitive function in individuals of culturally and linguistically diverse background poses considerable challenges for the psychologist, particularly when English proficiency is limited. This study explored the effects of diverse cultural background and non-Western educational background on Wechsler Adult Intelligence Scale–Third edition (WAIS-III) and Wechsler Memory Scale–Third Edition (WMS-III) performances in moderate–severe traumatic brain injury within an outpatient rehabilitation setting. Participants were aged 16–65 years and met careful selection criteria. IQ, index and age-scaled subtest scores were compared across three groups: (a) English-speaking background ($n = 130$), (b) culturally and linguistically diverse background and education completed in English ($n = 33$), and (c) culturally and linguistically diverse background and non-English education ($n = 33$). Cultural backgrounds included people of Asian, European, Middle Eastern, African and Oceania origin. Results were that the English-educated culturally and linguistically diverse group performed lower than the English-speaking background group on some verbal WAIS-III measures; effect sizes were small–moderate. The non-English-educated culturally and linguistically diverse group performed lower than both groups on several WAIS-III and one WMS-III measure, with large effect sizes. Clinical implications included the need for caution in interpreting test scores to avoid diagnostic errors and the need for further development of valid assessment tools.

Key words: *Bilingualism/multilingualism, cognitive disorders, cross-cultural psychology, memory and cognition, neuropsychology.*

Australia is a country of high cultural diversity: approximately one quarter of the population have at least one parent born overseas and during the last two decades there have been increased levels of migration from non-Western countries, particularly within Asia (Australian Bureau of Statistics, 2008). As a result, psychologists within health and other services are increasingly asked to assess cognitive function in people of culturally and linguistically diverse (CALD) background. Within rehabilitation settings, determining the impact of acquired brain injury on cognitive function has widespread implications for diagnosis, formulation of treatment and management guidelines and access to specific services and therapies. The validity of such assessments for individuals of CALD background has been questioned (Echemendia, 2007), and within the Australian context relatively few studies have examined the effects of cultural factors on test performances.

Most of the existing research has compared the test performances of CALD groups who were Western-educated against those of Caucasian background. Within the standardisation samples of the Wechsler Adult Intelligence Scale–Third edition (WAIS-III) (Wechsler, 1997a) and Wechsler Memory Scale–Third Edition (WMS-III) (Wechsler, 1997b) African American and Hispanic subjects scored lower than Caucasian subjects, particularly on WAIS-III factors (Heaton, Taylor, & Manly, 2003). African American subjects were more likely than other groups to be misclassified as impaired using a cut-off score of 1 *SD* below the mean (Heaton et al., 2003). Similar findings have been reported in relation to the Wechsler Adult Intelligence Scale–Revised (WAIS-R) (Wechsler, 1981)

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(Kaufman, McLean, & Reynolds, 1988; Razani, Burciaga, Madore, & Wong, 2007; Reynolds, Chastain, Kaufman, & McLean, 1987; Shuttleworth-Jordan, 1996) and for US Hispanic subjects on the Wechsler Memory Scale–Revised (WMS-R) (Wechsler, 1987) (Demsky, Mittenberg, Quintar, Katell, & Golden, 1998).

Australian controls of CALD background performed lower than those of English-speaking background on WAIS-R Performance IQ and WAIS-R Picture Completion subtest, but not on WMS-R measures (Carstairs, Myors, Shores, & Fogarty, 2006). In the same study, CALD individuals with a first language other than English also scored lower on WAIS-R Vocabulary and Verbal IQ than people whose first language was English (Carstairs et al., 2006). New Zealand Maori subjects performed lower on some WAIS-R and WMS-R measures than their white counterparts (Ogden, Cooper, & Dudley, 2003).

Cultural differences on the Wechsler scales have also been demonstrated in patient groups, including people with mixed neuropsychiatric disorders (Boone, Victor, Wen, Razani, & Ponton, 2007) and HIV-positive groups (Manly, Miller, et al., 1998), as well as in elderly populations (e.g., Baird, Ford, & Podell, 2007; Lucas et al., 2005; Manly, Jacobs, et al., 1998). This research, however, has been confined to North American populations.

The above evidence suggests that among people educated in the West with proficient English language skills, neuropsychological test performances may be associated with cultural background. Most of this research has been conducted with cultural groups such as African American and Hispanic subjects, which are prominent in North America and therefore further exploration is required in the Australian context, particularly with acquired injury groups. CALD individuals who have arrived more recently from Asian, African and Middle Eastern regions are likely to have non-Western educational backgrounds and may have limited English proficiency. More complex issues arise in assessing the cognitive function of this group (Artiola i Fortuny, 2004). Standardised tests, culturally and linguistically specific normative data and clinicians with relevant language skills are not available for many community cultural groups. The WAIS-III and WMS-III tests are available in 18 languages, but these are mostly European, with no African or Middle Eastern languages and few Asian languages represented (Harris, Tulsky, & Schultheis, 2003). As a result, the use of interpreters and reference to generic normative data are widespread clinical practice (Echemendia & Harris, 2004). Guidelines for conducting assessments with interpreters have been developed by the American Academy of Clinical Neuropsychology (Heilbronner, 2007) and others (e.g., Miletic, Piu, Minas, Solk, & Klimidis, 2006). It has been argued, however, that the results obtained under these circumstances are invalid and that conducting no testing may be preferable (e.g., Artiola i Fortuny & Mullaney, 1998; Iverson, 2000).

To our knowledge, there is no published research of the performances on English-language editions of the WAIS-III and WMS-III of people with largely non-Western education and variable English proficiency. Lower scores are expected under these conditions as a result of issues such as different quality of educational background relative to that of Western schooling (Shuttleworth-Edwards et al., 2004); less developed test-taking skills due to the lack of a shared format between test taking and education (e.g., Agranovich & Puente, 2007; Iverson, 2000; Nell, 2000; Rogoff & Chavajay, 1995; Weinstein, Fucetola, & Mollica, 2001); translation inaccuracies in interpreter-assisted examinations (Artiola i Fortuny & Mullaney, 1998); and third party observer effects on rapport and comfort (Gavett, Lynch, & McCaffrey, 2005; Weinstein et al., 2001). Exploration of the nature and extent of cultural effects on specific verbal and non-verbal test scores would provide some indication of the validity of present clinical practice.

The purpose of the current study was to explore the effects of cultural background on standardised test performances after moderate–severe traumatic brain injury (TBI) in a clinical convenience sample of individuals presenting to an outpatient rehabilitation service. WAIS-III and WMS-III test performances of three groups were compared: (a) people of English-speaking background, (b) people of CALD background educated in English, and (c) people of CALD background with non-English and largely non-Western education. It was hypothesised that CALD individuals educated in English would perform lower than their English-speaking counterparts on at least some WAIS-III measures. It was expected that CALD individuals with non-English education would obtain considerably lower scores than both groups on a number of WAIS-III and perhaps some WMS-III measures, particularly on tests that were more verbally based, such as WAIS-III Similarities.

Methods

Participants

Approval to access archival data was granted by Institutional Ethics Committees. Neuropsychological assessment data were extracted and analysed for consecutive referrals following TBI to an outpatient rehabilitation service from 2001 to 2007. A total of

410 individuals were referred, of whom 196 participants met the following criteria (Figure 1): (a) evidence that a TBI was incurred as indicated by documented loss of consciousness, loss of memory for events immediately before or after the incident, alteration in mental state, or focal neurological deficits (Malec et al., 2007); (b) moderate–severe TBI defined as post-traumatic amnesia (PTA) of ≥1 day, measured prospectively using the Westmead PTA scale (Shores, Marosszeky, Sandanam, & Batchelor, 1986) and either initial Glasgow Coma Scale (Teasdale & Jennett, 1974) ≤12 on hospital admission or neuroradiological evidence of trauma-related intracranial abnormalities (Malec et al., 2007) (those with PTA > 1 day who did not meet this second criterion were excluded given the possible confounding effects on mental state and PTA scores of trauma-associated factors, e.g., effects of analgesia for fractures, or systemic or psychological shock [Malec et al., 2007]); (c) aged between 16 and 65 years; (d) no prior neuropsychological examination; (e) neuropsychological assessment obtained after emergence from PTA and 6 weeks–2 years after the trauma; (f) no history of prior moderate–severe head trauma or other neurological condition such as pre-injury epilepsy, stroke, cerebrovascular disease, hypoxia; (g) no evidence of current significant psychiatric conditions such as depression, anxiety, psychosis or delusions, or chronic psychiatric condition such as schizophrenia; (h) no prior heavy alcohol or substance abuse requiring treatment or resulting in impaired occupational or social function, and no current hazardous levels of alcohol use as defined by Alcohol Use Disorders Identification Test score ≥ 10 (Babor, Higgins-Biddle, Saunders, & Monteira, 2001); (i) intact vision, adequate expressive language difficulties in terms of ability to formulate responses to tests and adequate upper extremity use to manipulate pen and test materials; (j) estimated pre-morbid intellectual function ≥70 based on Barona equation (Barona & Chastain, 1986) and no reports of special schooling; and (k) evidence of adequate levels of cooperation and motivation indicated by scores of ≥45 on trials 2 and 3 of the Test of Memory Malingering (Tombaugh, 1996) and/or Vocabulary minus Digit Span index ≤6 (Miller, Ryan, Carruthers, & Cluff, 2004) and/or Digit Span Scaled Score ≥5 (Iverson & Tulsky, 2003).

Three groups were defined on the basis of interview information: (a) English speaking, parents also English speaking and born in Australia or another English-speaking country; this included five individuals of indigenous background whose first and only language was English (English-speaking background, ESB, $n = 130$); (b) CALD background with at least one parent born in a non-English-speaking country and the individual's education completed in English, usually in Australia (CALD–English education, CALD-EE, $n = 33$); and (c) CALD background

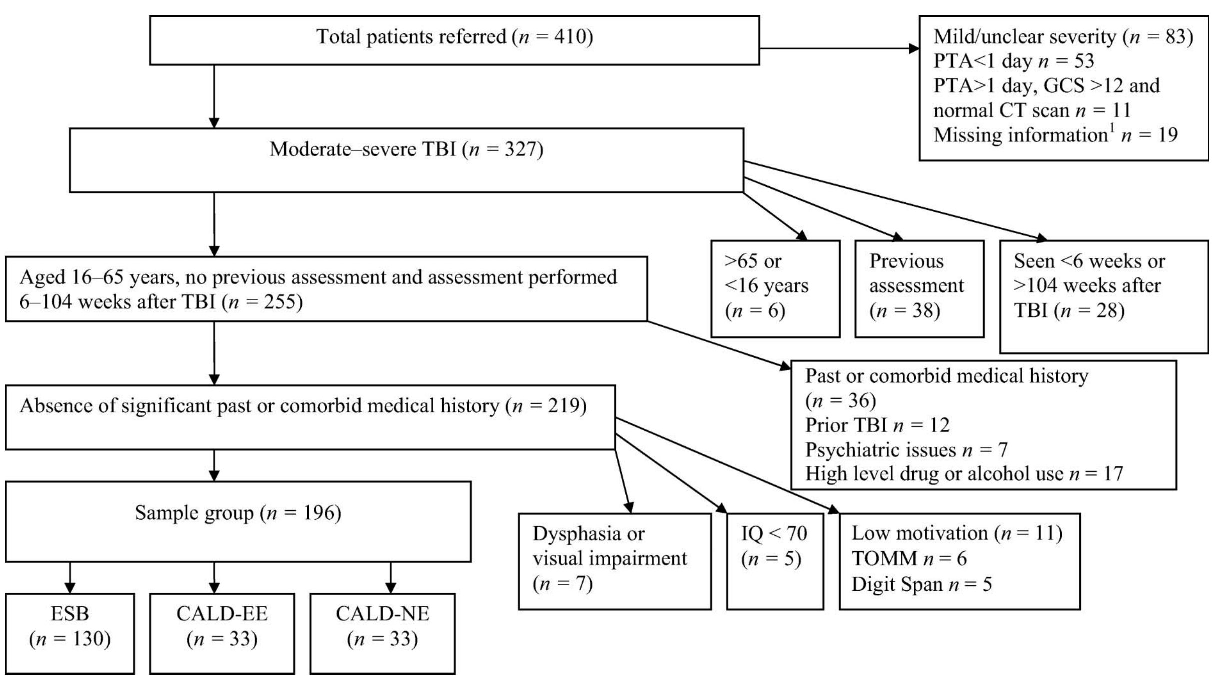

Figure 1. Participants referred for neuropsychological assessment after traumatic brain injury (TBI). [1]Missing documentation of GCS/PTA scoring, CT brain scan results, therefore TBI severity unclear. ESB = English-speaking background; CALD-EE = culturally and linguistically diverse, and educated in an English-speaking country; CALD-NE = culturally and linguistically diverse, and educated in a non-English-speaking country; GCS = Glasgow Coma Scale; PTA = post-traumatic amnesia.

and education in a non-English-speaking country (CALD–non-English educated, CALD-NE, $n = 33$).

Participants had a diverse range of cultural backgrounds and most of the CALD-NE backgrounds were non-Western; regions of origin are listed in Table 1.

Procedure

Participants completed a detailed interview and neuropsychological assessment with a clinical neuropsychologist (AW) between 2001 and 2007, as part of their rehabilitation program. Information about medical, educational and occupational history, drug and alcohol use, psychiatric and psychological state and compensation status was obtained from participants and/or a family member. Cultural background information included country of birth of self and parents, language of education and years in Australia. Relevant injury-related information was extracted from medical files as part of the assessment, including injury mechanism, weeks after injury, duration of PTA based on Westmead PTA scale scores (Shores et al., 1986), admission Glasgow Coma Scale (GCS) (Teasdale & Jennett, 1974) and computed tomography (CT) brain scan report.

Administration and scoring procedures were standardised, with linguistic interpretation of instructions and written translation of verbal materials as described below. Subtests reliant on the English alphabet (e.g., Letter–Number Sequencing) and tests with highly specific cultural or linguistic content such as vocabulary and general knowledge were not administered to CALD-NE participants. The following measures were administered to most individuals as part of a comprehensive neuropsychological assessment: (a) WAIS-III, Australian adaptation (Wechsler, 1997a) Similarities, Arithmetic, Digit Span, Picture Completion, Digit Symbol, Block Design, Matrix Reasoning and Symbol Search, allowing the derivation of the composite measures Performance Intelligence Quotient (PIQ), Perceptual Organisation Index (POI) and Processing Speed Index (PSI), and (b) WMS-III (Wechsler, 1997b) Logical Memory I and II and Family Pictures I and II.

Table 1. Region of origin of participants from diverse cultural backgrounds

	CALD-EE ($n = 33$)		CALD-NE ($n = 33$)	
Regional area	*n*	%	*n*	%
Africa	3	9.1	4	12.1
Asia	5	15.2	15	45.5
Europe	11	33.3	4	12.1
Middle East	10	30.3	6	18.2
Oceania	4	12.1	4	12.1

Note. CALD-EE = culturally and linguistically diverse, and educated in an English-speaking country; CALD-NE = culturally and linguistically diverse, and educated in a non-English-speaking country.

Additional measures administered to ESB and CALD-EE participants were (a) WAIS-III: Vocabulary, Information and Letter–Number Sequencing, allowing derivation of Verbal Intelligence Quotient (VIQ), Verbal Comprehension Index (VCI) and Working Memory Index (WMI), and (b) WMS-III: Verbal Paired Associates I and II.

Estimation of pre-morbid full-scale intellectual quotient was based on age, years of education, sex and occupation using the Barona equation (Barona & Chastain, 1986). This was chosen to avoid the language or cultural bias of using tests of reading ability such as the Wechsler Test of Adult Reading (WTAR) (Psychological Corporation, 2001) for people not schooled in English, or formulas that include WAIS-III subtests, for example, OPIE-3 (Schoenberg, Scott, Duff, & Adams, 2002), which might be reduced as a result of the TBI. In applying the Barona equation, the value of 8.81 for "White" was used for all participants given that cultural backgrounds in Australia do not match those in the United States; for region the mean value of 1.34 was used.

Within the CALD-NE group, 14 participants were assessed without an interpreter because their stated primary language was English, they expressed a preference to be seen without an interpreter and English proficiency was considered fluent on prior interview. The other 19 CALD-NE participants were assessed with a professional interpreter who was trained and credentialed in health-care assessments. More than 80% of interpreters had further specialised training by the area health service on brain injury and assisting with neuropsychological assessments. Interpreter-assisted assessments followed recommended Australian (Miletic et al., 2006) and US guidelines (Heilbronner, 2007) as follows. Prior to the assessment, tests of verbal memory and verbal reasoning were translated in writing; the interpreter was familiarised with those materials and with standardised test administration procedures; and culturally specific information that might be relevant to the assessment was elicited. (Translation of materials for one individual from southern Sudan could not be written because the professional interpreter was fluent but not literate in that language, due to severe disruption to education in that region as a result of war.) During the assessment, standard instructions were translated, with repetition or clarification when necessary by the examiner, without providing assistance with the task.

Results

Results were analysed using SPSS (SPSS for Windows, Rel 14.0.0, 2005, SPSS Inc, Chicago, IL, USA).

Demographic variables and injury characteristics were compared across groups using one-way ANOVA for interval level variables and chi-square test analysis for categorical variables (Table 2). Age in years showed a significant main effect of group; post hoc pair-wise comparisons showed that the CALD-NE group was significantly older than the other groups. Age-adjusted standard scores were used to allow for age differences. No group differences were found for sex, years of education, estimated pre-morbid intelligence, pre-injury occupational type, or post-injury employment status. Approximately 25% of participants had a motor vehicle or workers' compensation claim; there was no difference between groups. The groups did not differ on the injury characteristics of injury mechanism, weeks since injury, duration of PTA, GCS score, or presence or absence of abnormality on CT brain scan.

To determine normality of distribution for dependent variables, kurtosis, skewness and Shapiro–Wilks test values were calculated and histograms, normal Q-Q plot and box plots were inspected. Although not all criteria were met for every variable, the distribution of each dependent variable was approximately normal within each group, according to recommended guidelines (Peat & Barton, 2005). The presence of significant relationships between dependent variables and interval level demographic and injury variables were investigated by the inspection of scatter plots and the calculation of Pearson correlation coefficients. Significant relationships were seen between the dependent variables and years of education and duration of PTA. One dependent variable (WMS-III Logical Memory II) was significantly and positively associated with age; no other test scores

Table 2. Demographic and injury characteristics vs. group ($M \pm SD$)

	N	ESB ($n = 130$)	CALD-EE ($n = 33$)	CALD-NE ($n = 33$)	*F* (*df*)	*p*
Age (years)	196	30.7 ± 12.0	27.2 ± 10.6	43.9 ± 13.1	19.629 (2,193)	< .001
Range		16–64	16–54	19–65		
Sex: male/female	196	98/32	27/6	27/6	1.041[a] (2,196)	.594
Years of education	196	11.0 ± 2.2	11.0 ± 1.8	10.8 ± 3.2	0.099 (2,193)	.906
Range		8–20	8–16	1–15		
Interpreter yes/no	196	0/130	0/33	19/14	–	
Years in Australia if born overseas		–	14.5 ± 8.8 *n* = 16	14.4 ± 11.8 *n* = 33	0.001	.975
Range			2–39	0–26		
Pre-morbid IQ	196	96.1 ± 8.3	95.9 ± 6.4	97.4 ± 9.7	0.380 (2,193)	.694
Range		86–116	87–117	82–108		
Occupation, *n* (%)	192				6.202[a] (2,192)	.185
Professional/manager		24 (19)	12 (36)	5 (16)		
Student/trade/operator		45 (35)	8 (24)	9 (29)		
Labourer		59 (46)	13 (39)	17 (55)		
Post-injury employment, *n* (%)	192				0.881[a] (2,192)	.644
Working		36 (28)	7 (21)	7 (23)		
Not working		92 (72)	26 (79)	24 (77)		
Compensation, *n* (%)	196				5.875[a] (2,196)	.053
Yes		26 (20)	10 (30)	13 (39)		
No		104 (80)	23 (70)	20 (61)		
Injury mechanism, *n* (%)	189				7.506[a] (2,189)	.111
Road traffic accident		84 (68)	23 (72)	16 (48)		
Fall		13 (11)	5 (15)	9 (27)		
Assault		26 (21)	5 (15)	8 (24)		
Weeks after injury	196	28.2 ± 21.8	25.3 ± 20.4	25.7 ± 17.9	0.356 (2,193)	.701
Range		6–97	7–102	8–95		
PTA duration (days)	196	29.7 ± 28.6	27.8 ± 21.2	37.4 ± 33.7	1.157 (2,193)	.317
Range		1–140	4–75	1–146		
GCS score	173	8.2 ± 4.1	8.8 ± 3.6	9.4 ± 4.1	1.106 (2,170)	.333
Range		3–15	3–15	3–15		
CT brain scan, *n* (%)	195				2.160[a] (2,195)	.340
Abnormal		119 (92)	28 (85)	31 (94)		
Not abnormal		10 (8)	5 (15)	2 (6)		

Notes. CT = computed tomography; ESB = English-speaking background; CALD-EE = culturally and linguistically diverse, and educated in an English-speaking country; CALD-NE = culturally and linguistically diverse, and educated in a non-English-speaking country.
Analysis of variance, one between-groups factor with two or three levels; or chi-square test for categorical data.
[a]Chi-square test.

were significantly correlated with age. To determine the presence of significant relationships between dependent variables and categorical demographic and injury variables, box plots were inspected followed by t-tests. There was a significant effect for sex for some WAIS-III and WMS-III measures, with female subjects obtaining higher scores. There were no significant associations between dependent variables and weeks after injury, injury mechanism or compensation status. Given these relationships with neuropsychological test score variables, years of education, duration of PTA and sex were included as covariates in subsequent analyses.

Intelligence quotients, index scores and age-scaled scores were compared across groups on univariate ANCOVA. Group was the between-subjects independent variable, with three levels for most measures and two levels for those measures that were administered to ESB and CALD-EE subjects only. Years of education, duration of PTA and sex were entered as covariates in all analyses. To minimise the probability of Type 1 error over 23 comparison tests, the Hochberg correction was applied (Hochberg & Benjamini, 1990). Tests were ranked 23–1 by ascending probability value with lower *p*s ranked more highly. For each test p was multiplied by the rank; when this was $< .05$ that test and those of higher rank were considered significant, according to the Hochberg and Benjamini (1990) protocol. When the overall group effect was significant, post hoc comparisons were conducted to determine pair-wise differences, applying $p < .01$ for significance.

The analyses of covariance demonstrated an overall main effect of group for the WAIS-III composite measures of PIQ, POI and VIQ. Significant group differences were also evident for WAIS-III subtests Similarities, Picture Completion, Block Design and Vocabulary. A significant group effect was also shown on the WMS-III Logical Memory I subtest, as shown in Table 3. Pair-wise comparisons indicated that the ESB group performed higher than the CALD-NE group for PIQ, POI, Similarities, Picture Completion, Block Design and Logical Memory I. The CALD-EE group scored more highly than CALD-NE for PIQ, POI, Picture Completion and Block Design. ESB participants performed more highly than CALD-EE for VIQ, Vocabulary and Similarities. When pair-wise test differences were significant, effect sizes were calculated using Cohen's *d* (Zakzanis, 2001) and most were medium ($\geq .5$) or large ($\geq .8$), as shown in Table 4.

Post hoc analysis of CALD-NE data was conducted to explore whether lower test scores were associated with fewer years in Australia and/or interpreter-assisted assessments. Tests were selected for analysis if there was a significant group effect and $N \geq 25$; these were WAIS-III: PIQ, POI, Similarities, Picture Completion and Block Design. Pearson correlation coefficient of test scores by years in Australia was significant for WAIS-III PIQ, $r_{(n=30)} = .378$, $p = 0.039$; other variables did not reach significance. Scores of interpreter-assisted and -non-assisted assessments were subjected to univariate ANCOVA. Significantly lower scores for the interpreter-assisted group were obtained for WAIS-III POI and Similarities and effect sizes were large, as shown in Table 5.

Discussion

The results of this study indicated that following moderate–severe TBI, neuropsychological performances were significantly related to cultural background. Specifically, the CALD-EE group obtained lower scores than the ESB group on the WAIS-III composite measure VIQ and WAIS-III subtests Vocabulary and Similarities; effect sizes were small–moderate. The CALD-NE group, some of whom were assessed with interpreter assistance, obtained lower scores than the ESB group on almost half of the measures used. Significantly lower scores were returned on WAIS-III composite measures PIQ and POI, WAIS-III subtests Picture Completion, Block Design and Similarities subtests and WMS-III Logical Memory I subtest. Effect sizes were large. The CALD-NE group returned significantly lower scores than the CALD-EE group on WAIS-III PIQ, POI, Picture Completion and Block Design.

The finding that CALD-EE individuals scored lower than ESB individuals on some WAIS-III verbal measures supported existing research that demonstrated significant cultural effects among people with similar education backgrounds in control and patient groups. Consistent with previous findings, the cultural differences occurred on intelligence rather than memory subtests (e.g., Boone et al., 2007; Carstairs et al., 2006). In contrast to the findings of Carstairs et al. (2006) there were no differences between CALD-EE and ESB subjects on WAIS-III measures of perceptual organisation, and effect sizes on those tests that differentiated these two groups were small–moderate (0.4–0.5) compared to those in control groups (e.g., Carstairs et al., 2006; Kaufman et al., 1988; Reynolds et al., 1987). This may be interpreted to suggest that there was an attenuation of the cultural effect as a result of cognitive impairment after brain injury. Nevertheless, cultural factors should be considered in interpreting verbal WAIS-III results in CALD-EE individuals after moderate–severe TBI.

The CALD-NE group performed lower than the other groups but, contrary to expectation, reductions were most prominent on perceptual organisation tasks rather than verbal tasks. Given moderate–large

Table 3. Composite and subtest age-scaled scores

WAIS-III or WMS-III measure	ESB $M \pm SD$ (Range)	CALD-EE $M \pm SD$ (Range)	CALD-NE $M \pm SD$ (Range)	*F* (*df*)	*p*
WAIS-III					
Performance IQ	90.9 ± 13.7 (67–130) *n* = 125	88.3 ± 13.0 (58–114) *n* = 33	79.0 ± 11.2 (63–117) *n* = 30	10.14 (2,185)	< .0001[b,c]
Perceptual Organisation Index	94.3 ± 14.0 (70–130) *n* = 126	92.3 ± 13.3 (65–123) *n* = 33	81.8 ± 11.7 (67–118) *n* = 31	11.07 (2,187)	< .0001[b,c]
Processing Speed Index	85.6 ± 12.2 (57–128) *n* = 125	82.9 ± 12.3 (54–117) *n* = 32	78.9 ± 11.8 (63–108) *n* = 27	3.19 (2,181)	.043
Similarities	8.2 ± 2.8 (3–18) *n* = 130	7.0 ± 1.9 (2–10) *n* = 33	5.7 ± 2.8 (1–10) *n* = 30	13.05 (2,190)	< .0001[a,b]
Arithmetic	9.0 ± 3.1 (2–16) *n* = 130	7.9 ± 3.1 (3–13) *n* = 33	8.0 ± 2.6 (3–13) *n* = 31	3.81 (2,191)	.024
Digit Span	9.5 ± 2.4 (5–16) *n* = 130	8.9 ± 2.7 (5–17) *n* = 33	8.2 ± 2.6 (3–15) *n* = 33	3.31 (2,193)	.039
Picture Completion	8.4 ± 3.0 (4–18) *n* = 129	7.6 ± 2.9 (3–15) *n* = 33	5.2 ± 2.1 (2–12) *n* = 33	14.98 (2,192)	< .0001[b,c]
Digit Symbol	6.8 ± 2.4 (2–14) *n* = 127	6.4 ± 2.4 (1–14) *n* = 32	5.9 ± 2.3 (3–11) *n* = 31	1.63 (2,187)	.198
Block Design	9.3 ± 2.7 (4–16) *n* = 126	9.2 ± 2.7 (4–15) *n* = 33	7.3 ± 2.3 (4–13) *n* = 32	6.63 (2,188)	.002[b,c]
Matrix Reasoning	9.8 ± 2.9 (4–16) *n* = 126	9.6 ± 2.8 (4–15) *n* = 32	8.5 ± 3.0 (4–14) *n* = 32	2.33 (2,187)	.100
Symbol Search	7.8 ± 2.7 (1–16) *n* = 126	7.3 ± 2.7 (1–13) *n* = 32	6.3 ± 2.8 (2–12) *n* = 27	3.43 (2,182)	.035
Verbal IQ[1]	93.3 ± 13.8 (66–131) *n* = 126	87.2 ± 13.0 (63–110) *n* = 30	–	9.26 (1,154)	.003[a]
Verbal Comprehension Index[1]	92.9 ± 14.3 (65–136) *n* = 126	87.5 ± 12.7 (57–109) *n* = 30	–	7.29 (1,154)	.008
Working Memory Index[1]	93.9 ± 14.1 (57–126) *n* = 125	88.1 ± 15.2 (63–117) *n* = 31	–	5.56 (1,154)	.020
Vocabulary[1]	8.9 ± 3.0 (3–17) *n* = 126	7.5 ± 3.1 (1–13) *n* = 30	–	11.06 (1,154)	.0001[a]
Information[1]	8.9 ± 2.8 (4–17) *n* = 128	8.8 ± 2.5 (4–13) *n* = 30	–	.072 (2,156)	.789
Letter–Number Sequencing[1]	8.6 ± 2.8 (1–15) *n* = 125	7.9 ± 2.9 (2–13) *n* = 31	–	2.13 (1,154)	.146
WMS-III					
Logical Memory I	7.9 ± 3.1 (1–16) *n* = 127	6.8 ± 3.0 (1–11) *n* = 33	5.9 ± 2.7 (1–12) *n* = 29	6.158 (2,186)	.003[b]
Logical Memory II	7.9 ± 3.3 (1–17) *n* = 127	7.4 ± 2.7 (1–12) *n* = 33	7.3 ± 3.3 (1–13) *n* = 28	.331 (2,185)	.719
Family Pictures I	7.6 ± 3.3 (1–16) *n* = 124	6.9 ± 3.0 (1–14) *n* = 32	5.3 ± 3.8 (1–15) *n* = 17	4.425 (2,170)	.013
Family Pictures II	7.4 ± 3.5 (1–16) *n* = 124	6.8 ± 3.0 (1–14) *n* = 32	5.5 ± 3.3 (2–13) *n* = 17	3.224 (2,170)	.042
Verbal Paired Associates I[1]	8.6 ± 3.4 (2–15) *n* = 123	7.0 ± 3.0 (1–13) *n* = 29	–	7.002 (1,150)	.009
Verbal Paired Associates II[1]	8.1 ± 2.9 (1–14) *n* = 123	6.7 ± 3.0 (2–12) *n* = 29	–	5.954 (1,150)	.016

Notes. ESB = English-speaking background; CALD-EE = culturally and linguistically diverse, and educated in an English-speaking country; CALD-NE = culturally and linguistically diverse, and educated in a non-English-speaking country; WAIS-III, Wechsler Adult Intelligence Scale–Third Edition; WMS-III, Wechsler Memory Scale–Third Edition.
Analysis of covariance, one between-groups factor with two or three levels, covariates years of education, post-traumatic amnesia duration and sex, post-hoc comparisons conducted only for significant group effects.
[a]CALD-EE significantly lower than ESB; [b]CALD-NE significantly lower than ESB; [c]CALD-NE significantly lower than CALD-EE.
[1]ESB and CALD-EE groups only.

(0.7–1.1) effect sizes, the differences were clinically significant. This indicates that tests such as Block Design and Picture Completion are susceptible to cultural bias. Equivocal findings ($p > .003$ and $< .05$) were returned for WAIS-III PSI, Arithmetic, Digit Span and Symbol Search and WMS-III Family Pictures I and II, suggesting that cultural effects are probable on these measures. Perfor-

mances on WAIS-III Matrix Reasoning and Digit Symbol and WMS-III Logical Memory II were comparable across groups ($p > .05$), suggesting that capacities of CALD-NE individuals were more accurately estimated on these subtests. The finding of reduced scores on Logical Memory I ($M = 5.9$) and yet similar Logical Memory II scores ($M = 7.3$) may have reflected cultural differences in responses to testing. For example there may have been a lessening of initial discomfort with the unfamiliar testing situation, given that Logical Memory I was one of the first tests administered. This requires further study.

Table 4. Effect sizes for group comparisons (where pairwise group difference significant)

WAIS-III or WMS-III composite or age-scaled score	Group comparison		
	ESB–CALD-NE	CALD-EE–CALD-NE	ESB–CALD-EE
WAIS-III			
Performance IQ	0.9	0.8	
Perceptual Organisation Index	0.9	0.8	
Similarities	0.9		0.5
Picture Completion	1.1	0.9	
Block Design	0.7	0.7	
Verbal IQ[1]			0.4
Vocabulary[1]			0.5
WMS-III			
Logical Memory I	0.7		

Notes. ESB = English-speaking background; CALD-EE = culturally and linguistically diverse, and educated in an English-speaking country; CALD-NE = culturally and linguistically diverse, and educated in a non-English-speaking country; WAIS-III, Wechsler Adult Intelligence Scale–Third Edition; WMS-III, Wechsler Memory Scale–Third Edition.
Effect sizes calculated using Cohen's *d* for significant pairwise comparisons ($p < .01$), where there was a main effect of group in analysis of covariance.
[1]Verbal IQ and Vocabulary: ESB and CALD-EE groups only.

Multiple factors may underlie the lower scores of the CALD-NE group. Educational background is likely to be a salient factor, given that the skills that are emphasised in non-Western education are poorly matched to neuropsychological test-taking skills and attitudes, whereas Western education emphasises similar skills (Brandt, 2007; Nell, 2000; Rogoff & Chavajay, 1995; Shuttleworth-Edwards et al., 2004; Weinstein et al., 2001). In addition, test materials contain culturally specific pictures and tasks that are less familiar to people of other cultures; and translation inaccuracies and third party observer effects may impact adversely on scores. Reduced scores on tests of perceptual organisation may result from the lower emphasis on spatial relations in some non-Western cultures (e.g., Ardila & Moreno, 2001); and different patterns of brain activity have been observed during specific tasks as a function of linguistic and cultural background (Cantlon & Brannon, 2006).

Within the CALD-NE group, fewer years of residence in Australia was associated with lower performance on WAIS-III PIQ, and interpreter-assisted assessments were associated with lower scores on WAIS-III POI and WAIS-III Similarities. Given that length of residence and English proficiency (assumed to vary with interpreter use) may reflect level of acculturation (Harris et al., 2003), it may be that performances were reduced when levels of acculturation were lower, as demonstrated in other research (e.g., Boone et al., 2007; Kennepohl, Shore, Nabors, & Hanks, 2004; Razani et al., 2007; Varghese, 2005). Other factors may be that scores were lower on interpreter-assisted assessments due to third party observer effects (Gavett et al., 2005) and negative stereotype threat, demonstrated in some studies (e.g., Steele & Aronson, 1995), but not others (e.g., Coleman-Carew, 2002; Touradji, 2004).

There were a number of limitations of the current study. The sample sizes for the CALD groups were

Table 5. CALD-NE scores vs. presence of interpreter

Composite or age-scaled score	Interpreter-assisted ($M \pm SD$)	No interpreter ($M \pm SD$)	F (df)	p	Effect size
WAIS-III					
Performance IQ	75.3 ± 7.5 $n = 18$	84.5 ± 13.7 $n = 11$	2.757 (1,28)	.109	
Perceptual Organisation	78.8 ± 8.7 $n = 19$	88.2 ± 13.3 $n = 12$	4.64 (1,29)	.041	0.9
Similarities	4.7 ± 2.4 $n = 19$	7.2 ± 2.6 $n = 12$	6.576 (1,28)	.017	1.0
Picture Completion	5.1 ± 1.5 $n = 19$	5.4 ± 2.7 $n = 14$	.054 (1,31)	.817	
Block Design	6.8 ± 2.3 $n = 19$	7.9 ± 2.4 $n = 13$	1.116 (1,30)	.300	
WMS-III					
Logical Memory I	5.3 ± 2.6 $n = 16$	6.6 ± 2.8 $n = 13$	1.675 (1,27)	.208	

Notes. CALD-NE = culturally and linguistically diverse, and educated in a non-English-speaking country; WAIS-III, Wechsler Adult Intelligence Scale–Third Edition; WMS-III, Wechsler Memory Scale–Third Edition.
Analysis of covariance for test measures for which cultural group was significant and $N \geq 25$, one between-groups factor with two levels, covariates years of education, post-traumatic amnesia duration and sex; effect sizes calculated using Cohen's *d*.

relatively small and there was a wide diversity of cultural regions of origin within each group. Given small numbers, it was not possible to examine the effects of factors such as divergence from English language and Western culture (Ardila & Moreno, 2001); limited formal education (Ardila, Rosselli, & Ross, 1989; Petersson, Reis, & Ingvar, 2001) and the impact of physical and psychological trauma from refugee experiences (Steel & Silove, 2001). The results do not provide a basis for correcting scores according to cultural background but rather serve to underline the importance of considering cultural factors when conducting neuropsychological assessments. Group differences were not detected on the majority of WMS-III subtests, but it is likely that differences would have been detected had the group numbers been larger. The CALD-NE group was older than the other groups, but age-adjusted standard scores were analysed; and age was not significantly correlated with scores, with the exception of one measure that did not show a significant group effect. It is therefore considered that the age difference between groups did not contribute to the results. The groups did not differ on other demographic factors such as sex, years of education and occupation, nor on injury characteristics such as PTA duration, GCS on admission, neuroradiological abnormality, compensation status or post-injury employment status. We would therefore argue that the group differences reflected the effects of cultural background. Finally, as a retrospective study, not all tests were administered to all participants, and further exploration of the results would have been provided by consideration of other issues that may impact on neuropsychological performances, such as bilingualism, level of acculturation, English language skills and socioeconomic status.

Clinically, these results indicate that after moderate–severe TBI, the capacities of CALD-NE individuals, particularly those with limited English proficiency, are likely to be underestimated on some WAIS-III and WMS-III measures, and individuals may be falsely misclassified as impaired unless caution is applied to test interpretation. There is an increased risk of diagnostic errors and inappropriate management and treatment recommendations when tests that are standardised in Western populations are applied to people of widely divergent cultural backgrounds. In order to maximise validity, cognitive assessments that are conducted with interpreters should adhere to the following guidelines (Heilbronner, 2007; Miletic et al., 2006). Prior to the assessment, tests of verbal memory and verbal reasoning should be translated in writing, the interpreter should be familiarised with those materials and with standardised test administration procedures and the interpreter should be asked about culturally specific information that might be relevant to the assessment. During the assessment, clarification may be required for the translation of some instructions and afterwards, the interpreter should be asked about any difficulties or ambiguities that may have impacted on test reliability. The current results highlight the importance of including direct observation and collateral information about adaptive function when assessing CALD individuals, given that test scores may underestimate cognitive capacity (Artiola i Fortuny & Mullaney, 1998; Shepherd & Leathem, 1999; Simpson, Mohr, & Redman, 2000). Furthermore, reports should highlight interpreter use, the normative comparisons made, cultural factors and the limitations of the approach (Heilbronner, 2007).

In conclusion, given the higher levels of migration to Australia from countries with widely divergent cultures and education systems, further research is needed to improve the validity of neuropsychological assessments with CALD-NE individuals. For larger community populations, such research may include the development of linguistically specific normative data for healthy controls with limited English proficiency. In addition, further efforts should be directed towards the development of culturally specific normative data for tests with acceptable validity and reliability for specific CALD groups in the Australian context. For example, the Colour Trails Test and modified versions of the Auditory Verbal Learning Test have been developed and validated for African and Thai populations (Maj et al., 1993). The current findings suggest that WAIS-III Matrix Reasoning and Digit Symbol subtests may be relatively free of cultural bias effects, but this requires confirmation through the prospective study of larger healthy control groups. Finally, given that English-language proficiency, bilingualism, acculturation and socioeconomic status may modulate the effect of cultural background on test performances, these variables should be assessed in future studies.

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